Water, Water Everywhere: Large Lake Monitoring in Southwest Alaska National Parks

By Jeff Shearer

"These pristine 'great lakes of Alaska' are fountains of pure water and nurseries of the Bristol Bay salmon. They are of incalculable worth to our nation and humanity going forward into an era of global climate change in a more crowded and polluted world. If there ever was a truly strategic commodity in the world, it is pure water, which Bristol Bay has a great abundance." - John Branson, Lake Clark National Park and Preserve historian, in *The Canneries, Cabins and Caches of Bristol Bay, Alaska*

Connections to the Land

Extending out from the western end of the Alaska Range onto the Alaska Peninsula spans a series of massive waterbodies that dominate the landscape. With names like Iliamna, Clark, Kukaklek, Nonvianuk, Naknek, Brooks, Becharof, and Ugashik, these lakes and their connecting rivers generate a network of freshwater that has bound cultures and ecosystems for generations (*Figure 1*).

Bristol Bay salmon, especially sockeye salmon (*Oncorhynchus nerka*), are the life blood flowing through this freshwater network. The role salmon play in transporting critical marine-derived nutrients to freshwater and terrestrial systems across all trophic levels from plants to bears has been well documented (*e.g. Gende et al. 2002, Naiman et al. 2002*). Lakes are an integral part of the pathway for those marine-derived nutrients to spread throughout the landscape.

The connections between salmon and the landscape serve as an important reminder that lakes are not microcosms whose influences stop at the shoreline as early limnologists once thought. Instead, lakes are better described as flow systems comprised of inflowing tributaries, outlets, and interconnected basins functioning as one contiguous system. As such, these systems are integrators of water, energy, nutrients, solutes, and pollutants from the landscape and atmosphere, and thus are ideal indicators of environmental change, especially climate change (*Adrian et al. 2009*).

Sentinels of Change

The physical and chemical composition of lakes are a direct reflection of the surrounding geology and climate. For example, many lakes in Lake Clark National Park and Preserve (LACL) have distinct "U-shaped" valleys reflecting their glacially-carved origins. The Iliuk Arm of Naknek Lake in Katmai National Park and Preserve (KATM) is gray in color due to ash runoff from the nearby Valley of Ten Thousands Smokes. Important processes and phenological events within a lake, such as duration of ice cover, thermal stratification, and water level fluctuations, are all dictated to some extent by the geologic and climatic setting of that lake. These processes, in turn, largely influence the biological productivity of lakes and associated wildlife species (e.g. salmon).

The goal of SWAN's lake monitoring program is to evaluate the long-term trends in water quality and surface hydrology in the large lake systems of KATM and LACL. We are monitoring the chemical and physical parameters of water that ultimately dictate the biological productivity of large lake systems and tracking how those parameters are affected by natural and anthropogenic influences. In an effort to maintain a holistic approach to monitoring these freshwater systems, we will integrate freshwater monitoring data with trends observed in other I&M programs, such as landscape processes (e.g. ice cover), glacial extent, and climate monitoring, to provide a more complete synopsis of changes throughout the watershed and potential implications of those changes on lake system dynamics.

Monitoring Approach

The volume of freshwater in southwestern Alaska parks is extraordinary, covering 12% of KATM's surface area alone. In order to monitor such a vast expanse of water, lakes were prioritized based on accessibility, management priority, and spatial representativeness (e.g. glacial vs. non-glacial waters, anadromous vs. non-anadromous). The majority of SWAN's efforts focus on the Lake Clark/Kontrashibuna and the Naknek/Brooks Lake systems. Naknek Lake and Lake Clark represent the largest and third largest lakes, respectively, in terms of surface area in the national park system.

In these lake systems, we collect a series of standardized measurements of water temperature, pH, dissolved oxygen, specific conductivity, turbidity and hydrology (lake level and lake discharge). We use a variety of instruments to collect these data, such as multiparameter water quality meters, automated data loggers, and temperature thermistors. Conditions in lakes vary in both space and time. We account for spatial variability by collecting data at randomly selected, spatially balanced sites throughout the lake basin (synoptic sites) where measurements are recorded at the water surface and

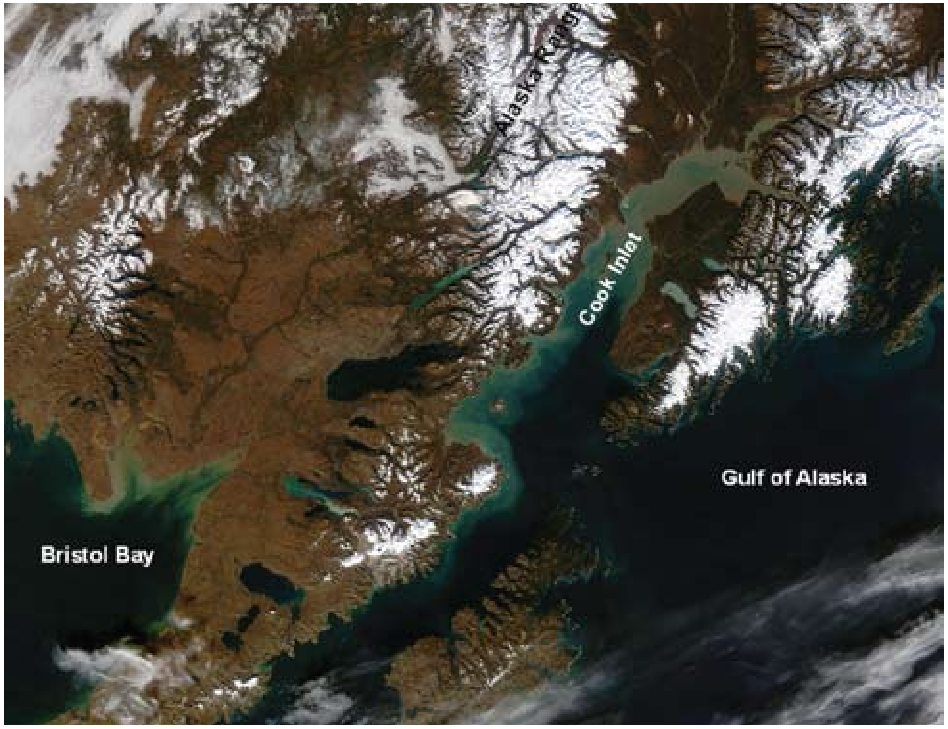

Figure 1. Oblique LandSat image of southwestern Alaska depicting the convergence of marine, mountain, and freshwater systems.

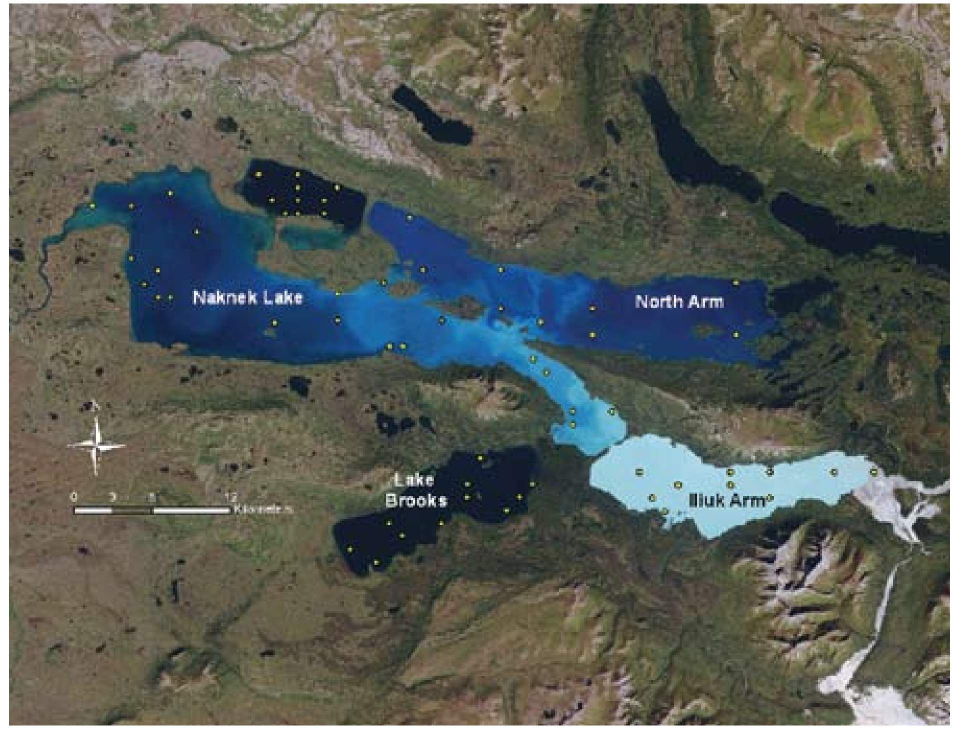

Figure 2. Synoptic sampling sites (yellow dots) for the Naknek/Brooks Lake system. Note the contrast between turbid waters of the Iliuk Arm versus clear waters of the North Arm. Within lake variability illustrates the importance of proper spatial sampling coverage.

at fixed intervals to a depth of 160 feet (50 m) (*Figure 2*).

Temporal variability is assessed by collecting hourly observations at a handful of predetermined sites (continuous deployment sites). Synoptic sites are sampled once per year during the mid-summer index period, whereas continuous deployment sites are monitored year round (within the lakes) or during the open water period (at outlets and inflowing tributaries).

Making Sense of the Data

Monitoring water quality and hydrology, especially through the use of automated data loggers, generates a tremendous volume of data. Appropriate data management procedures are critical to ensure proper archiving, processing, and synthesizing of the information collected. Additionally, SWAN has placed emphasis on making data available to park managers and the public through a variety of avenues, such as summary reports, resource briefs, and the network's website http://science.nature.nps.gov/im/units/swan/

Most freshwater monitoring activities have just started and trend analysis is not yet possible. However, several observations from Lake Clark have revealed the large degree to which these lakes systems are influenced by geologic and weather-related events. Typically, Lake Clark exhibits a turbidity gradient ranging from turbid glacial water in the upper lake to clear water in the lower lake. However, the 2009 eruptions of Mt. Redoubt changed the turbidity gradient. These eruptions blanketed much of the Lake Clark watershed with a layer of volcanic ash (*Figure 3A*). As the snow melted and washed into Lake Clark, the input of volcanic ash "homogenized" water clarity, creating turbid conditions lake-wide for much of the summer of 2009 (*Figure 3B*). Previous research on Lake Clark has suggested that sockeye salmon fry and least cisco (*Coregonus sardinella*), the two primary pelagic forage fish within the lake, partition themselves along a turbidity gradient. Least cisco tend to inhabit the more turbid upper lake while sockeye salmon fry tend to inhabit the lower lake. Future research will examine the biological ramifications of altering lake turbidity, whether resulting from natural or anthropogenic causes, on sockeye salmon fry growth and survival.

We are also continuously monitoring water temperature at these lakes through a series of permanent temperature arrays. The Lake Clark temperature array was established in September 2006 and measures water temperature in Lake Clark from near the surface to 330 ft (100 m) depth at 33-ft (10-m) intervals every hour year round (*Figure 4*).

In Lake Clark and other southwestern Alaska lakes, strong wind events vertically mix the water column, limiting stratification and disrupting thermocline formation. A thermocline is a layer of water with a steep temperature gradient that can strongly influence primary productivity and fish distribution within lakes. An example of these strong wind events occurred on July 21, 2009. Weather stations in LACL and KATM recorded wind gusts in excess of 80 mph (128 kph). The resulting wind-generated waves and subsequent water column mixing on Lake Clark and Naknek Lake caused surface water temperatures to drop 14.4°F (8° C) in less than a day (*see Figure 4*). Such an abrupt change is more common in shallow ponds and wetlands, but is relatively rare in large, deep lakes that typically moderate temperature changes on the surrounding landscape. We will continue to analyze the data to determine possible implications for drastic weather-induced condition changes on biological productivity.

Our 2009 field observations on Lake Clark remind us that the large lake systems of southwestern Alaska parks are driven by extremes. While researchers often report the average or "mean" of their collective observations, it is the variability and extremes that dictate the limits of these lake systems and how they function in their environment. Understanding how those extremes influence critical park resources, such as sockeye salmon, often leave park managers with more questions than answers. Add in the uncertainty surrounding climate change and the problem is only exacerbated. Through a simple, yet effective, long-term monitoring program, SWAN aims to provide answers for those 'great lakes of Alaska' and the NPS staff who oversee their preservation.

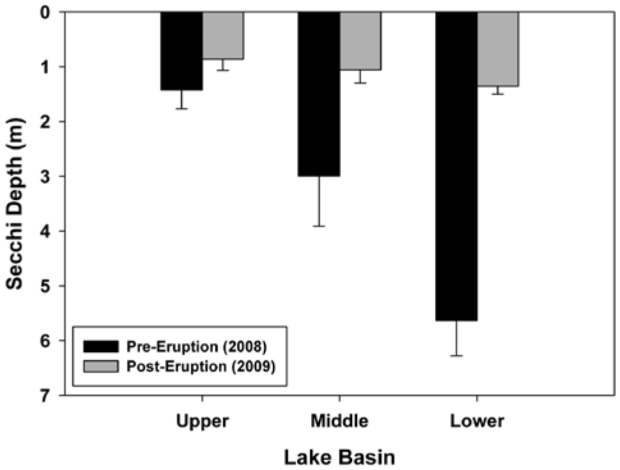

Figure 3. (A) (Left) Steam rises from Mt. Redoubt as volcanic ash blankets the landscape; (B) (Right) Secchi depth, a measure of water clarity (mean +/- 1 SD), of Lake Clark before and after the eruption of Mt. Redoubt.

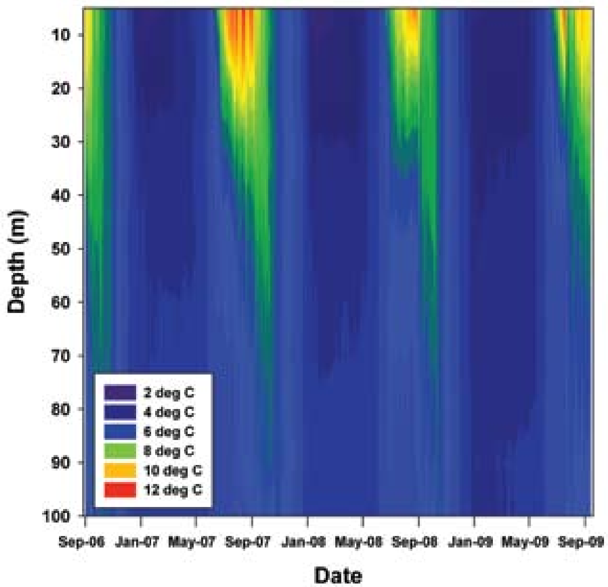

Figure 4. Isotherm of mean daily water temperature for Lake Clark showing patterns of summer stratification, inverse stratification in winter months (colder water near surface), and spring and fall isothermy (uniform temperature throughout water column).

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